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Improvement of Hot-Side Precipitator Performance with Sodium Conditioning--An Interim Report

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16. ABSTRACT

The article reports on a research project (sponsored by EPA, EPRI, and Southern Company Services) to evaluate sodium conditioning as a possible solution to performance deficiency problems encountered at a number of major utility plants during the development of an unexpected, time-dependent degradation of performance of hot-side electrostatic precipitators (ESPs) collecting ash from certain coals (usually low-sodium low-sulfur coals). The article concludes that sodium conditioning produced by sodium sulfate addition to the coal supply is an effective way to improve the performance of a hot-side ESP which has undergone the sodium-depletion high-resistivity pattern of performance deterioration. Although the reported results are believed to be of general significance, certain characteristics of the operating parameters at Gulf Power Co.'s Lansing Smith plant are noteworthy with regard to the success of the conditioning process. First, ash concentration and composition, and boiler design, allowed the addition of the required amount of sodium without creating boiler operating problems. Secondly, the calcium content of the coal was moderate, and there is some evidence that high calcium concentrations would require more sodium addition for the same degree of resistivity reduction. Applicability of the process for other ash chemistries and operating conditions remains to be determined.

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Electric Utilities	Stationary Sources	13I
Electrostatic Precipitators	Sodium Conditioning	07B 11M
Sodium	Hot-side Precipitators	21B
Corrosion		21D 20C
Fly Ash		
Electrical Resistivity		
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Improvement of Hot-side Precipitator Performance with Sodium Conditioning—An Interim Report

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The development of an unexpected, time-dependent degradation of performance of hot-side precipitators collecting ash from certain coals (usually low-sodium, low-sulfur coals) has caused serious problems at a number of major utility installations. A jointly funded research project was developed under the sponsorship of the U.S. Environmental Protection Agency, the Electric Power Research Institute, and Southern Company Services, Inc., to evaluate sodium conditioning as a possible solution to these performance deficiency problems.

The development of an unexpected, time-dependent degradation of performance of hot-side precipitators collecting ash from certain coals (usually low-sodium, low-sulfur coals) has caused serious problems at a number of major utility installations. One of the authors[1] recently offered an interpretation of the performance degradation based on the concept that a very thin layer of fly ash, tenaciously held to the collection electrode for a long time, develops very high resistivity. It has been demonstrated as a part of this research project that the layer adjacent to the collection electrode becomes deficient in sodium ions, the principal charge carrier. The phenomenon is sometimes called electrode polarization or sodium depletion. A detailed treatment of the sodium depletion experiments, as well as other related experiments, will be presented in future publications. This article gives a brief presentation of results obtained to date from a research program designed to implement a remedial approach (sodium conditioning) to this problem, on a full-scale installation.

Background

A jointly funded research project was developed under the sponsorship of the U.S. Environmental Protection Agency, the Electric Power Research Institute, and Southern Company Services, Inc., to evaluate sodium conditioning as a possible solution to performance deficiency problems experienced with hot-side precipitators installed on Units 1 and 2 of the Lansing Smith Plant of Gulf Power Company, located near Panama City, FL. The boilers for the plant are Combustion Engineering tangentially fired furnaces, with Unit 1 rated at 175 MW, and Unit 2 at 196 MW. Both units were retrofitted with hot-side precipitators in 1977, and the units initially passed normal compliance tests. However, performance deficiency problems appeared in 1978, especially during load rise conditions. A low-sulfur, low-sodium South African coal is the fuel normally used at Lansing Smith.

Prior to the use of sodium conditioning, a number of other potential remedial approaches were attempted. These included power-off rapping, reversible polarity transformer-rectifier (TR) sets, the use of improved TR set controls, ammonia conditioning, and precipitator washdowns. With the exception of precipitator washdowns, these procedures did not produce the desired level of performance. The washdowns did improve performance, but degradation would immediately begin again. The performance would reach unacceptable levels in a period ranging from one to two months, and an outage would be required to perform another washdown. Since the washing procedure placed an unacceptable operating constraint on the plant, a decision was made to evaluate sodium conditioning.

Research Program

The overall objectives of the research program were as follows:

- Evaluation of the effectiveness of boiler injection of sodium compounds as a means of improving precipitator performance after degradation has occurred by determining and analyzing precipitator performance immediately after a washdown, after degradation has occurred following the washdown procedure, and with sodium conditioning in progress.
- Evaluation of the effect of boiler injection of sodium compounds at the required dosage level on boiler operating characteristics.

- Determination of the cause of the performance degradation by analyzing layers of ash deposits, from the full-scale precipitator and from various laboratory apparatus, to confirm that prolonged passage of current produces ash layers having zones of depleted sodium concentration.
- Evaluation of chemical diffusion of sodium from an overlying conditioned ash layer into a layer of depleted sodium concentration as a means of reversing the effects of depletion.

For discussion purposes, the article will be divided into three phases: 1) design and construction of the sodium addition system, 2) field measurements on the boiler-precipitator system, and 3) laboratory studies.

Sodium Addition System

Previous work by Gooch, Bickelhaupt, and Sparks[2] has established that coprecipitation of sodium carbonate powder with high resistivity fly ash provides ineffective reduction of resistivity for cold-side precipitator applications. Laboratory work showed the magnitude of resistivity reduction that could be achieved with a given increment of sodium carbonate addition increased with increasing severity of mixing. It was concluded that coprecipitation of the fly ash and sodium carbonate powder did not provide the required degree of mixing between the two particulates. It was speculated that these observations would also be qualitatively applicable to hot-side sodium conditioning systems, although some successes have been reported[3] with hot-side coprecipitation of sodium compounds. Therefore, it was decided to investigate addition of a sodium compound to the coal supply prior to pulverization as a means of supplementing the sodium content of the fly ash. Essentially complete decomposition and volatilization of the conditioning agent is anticipated to occur in the boiler. This process should ensure that the condensing sodium compounds will be uniformly distributed and become an integral part of the fly ash surfaces. The boiler system under study has had previous experience with high sodium ashes having concentrations significantly greater than those required for resistivity reduction. As a result of this experience, no slagging or fouling problems were expected by plant personnel with the planned levels of sodium injection.

Southern Company Services personnel performed a study of the various options available to accomplish sodium conditioning via coal treatment. Two conditioning agents, sodium carbonate and sodium sulfate, were considered, as were wet and dry application methods. Sodium sulfate was chosen for the test because it was the most economical source ($90/ton delivered), and was readily available to the plant by truck. It was thought that a wet addition system would provide the most flexibility if one could be designed to meter accurately a solution to each of the coal feeders. However, laboratory solubility studies showed that stable solutions of the desired concentration (~ 40% by weight) could not be formed with the commercially available sodium sulfate by-product. As a result of this difficulty, a dry application procedure was selected.

The sodium sulfate by-product is delivered to the plant in 20-ton hopper trucks equipped with pneumatic pumps and is pneumatically conveyed into a 40-ton storage silo located beside the coal feeder belt. At Plant Lansing Smith, the coal is loaded into the bunkers once a day at a feed rate of 800 ton/hr for approximately 4 hr, with the exact amount dependent upon the amount of fuel burned the previous day. The sodium sulfate is delivered from the silo to the coal feeder belt by a screw feeder at a rate ranging from 0.21 to 0.52 lb sodium sulfate/100 lb coal, with the exact amount dependent upon the desired level of sodium oxide equivalent in the fly ash. The rate of 0.21 lb Na_2SO_4/100 lb coal produces approximately a 0.70% increment in the equivalent Na_2O concentration in the fly ash.

There was some concern about the loss of sodium sulfate and the development of concentration inhomogeneity as the coal passed through transfer points to the boiler. A simple shower head was installed over the coal belt prior to and after the sodium sulfate addition point to slightly wet the coal and provide a means of adhering the powder to the coal. Subsequently discussed chemical analysis data indicate this system was effective in uniformly distributing the conditioning agent in the fly ash. These data also indicate that the powder stays uniformly distributed while the coal is stored in the bunkers. It is believed that the success of this system is due to the uniform distribution of the sodium compound to the pulverizers and the burners.

Field Measurements

The field testing performed thus far has consisted of the following major segments:

- A "Baseline 1" series performed immediately after the precipitator had been washed after a unit outage.
- A "Baseline 2" series performed with the precipitator in a degraded condition of operation.
- A "Conditioning 1" series performed after a period of operation with the Na_2O content of the fly ash increased from ~0.3% to ~1.0%.
- A "Conditioning 2" series performed with the Na_2O content of the fly ash increased from ~0.3% to ~1.8%.

Each of these test series included extensive measurements to characterize the collection efficiency and the electrical operation of the precipitator. A long-term evaluation of this conditioning process is still underway at the Lansing Smith Plant,

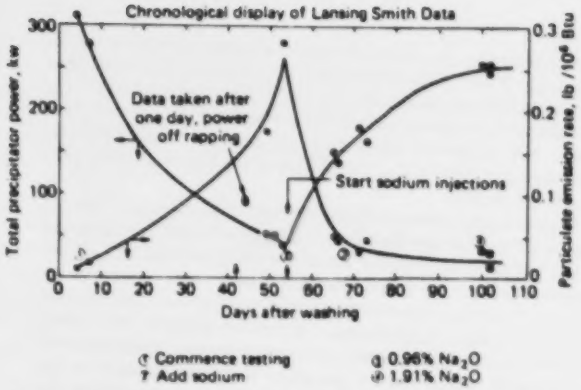
Chronological display of Lansing Smith Data
Total precipitator power, kw
Particulate emission rate, lb /10⁶ Btu
Data taken after one day, power off rapping
Start sodium injections
Days after washing
C Commence testing
A Add sodium
B 0.96% Na2O
D 1.91% Na2O

Figure 1. Chronological display of Lansing Smith data. Data taken from hot-side ESP which is followed by a cold-side ESP.

with sodium conditioning continuing at a rate that increases the Na_2O content of the fly ash from ~0.3% to ~1.3%.

Laboratory work on the Lansing Smith project is also currently in progress, and includes the following tasks:

- Chemical and physical characterization of fly ash obtained from precipitator hoppers and mass trains with and without sodium conditioning.
- Resistivity measurements on selected samples of the ash described above as a function of temperature and applied electric field.
- Various experiments with the above ash samples for the following purposes:

  —to confirm that prolonged application of voltage gives evidence of the formation of a zone of depleted sodium concentration;

  —to determine whether overlaying conditioned ash on a layer of depleted sodium concentration will reverse the effect of depletion.
- Various measurements to obtain evidence of sodium depletion in the ash from a section of collection electrode removed from the plant precipitator.
- Analysis of the performance of the precipitator using a mathematical model.

Results and Discussion

Precipitator Performance

Although certain aspects of the research program are still in progress as of this writing, sufficient results are available to allow useful conclusions to be obtained. Figure 1 provides a chronological display of precipitator power and particulate emissions from the hot-side precipitator as a function of days after washing. The high level of performance immediately after washing and the subsequent deterioration are evident in the data covering the time span day 5 through day 55. The recovery in precipitator power and the concomitant reduction in emission rates are apparent in the data obtained during days 55 through 102. The temporary recovery obtained during the degradation phase on day 42 was caused by an outage resulting from a boiler problem, which is normally accompanied by cooling of the precipitator system and power-off rapping. It is speculated that the reduced temperature allows surface back-diffusion of mobile sodium ions due to adsorbed water vapor, and that this process temporarily reverses the polarization process.

Table I provides efficiency data, percent penetration, precipitator power levels, specific collection areas, and representative values of total sodium oxide equivalent concentrations in fly ash undergoing collection for the indicated test series. It is apparent from these data that the sodium conditioning increased precipitator power by factors ranging from 3 to 5, and decreased penetration from the precipitator by factors ranging from 5 to 6. All of the mass concentration data given in Figure 1 and Table I were obtained at the outlet of the hot-side precipitator which is followed by a cold-side precipitator.

The relatively rapid response of ESP performance to the added sodium sulfate was somewhat unexpected, since it was known that the conditioning process would have to overcome the deleterious effects caused by the presence of the tenaciously adhering layer of high resistivity, sodium-depleted ash. It was speculated that washing the precipitator would be required to realize the full benefits of the sodium-enriched fly ash. However, the rapid response can be rationalized by consideration of the effects of chemical diffusion of sodium from the conditioned ash layer into the depleted zone.

The possible effects of chemical diffusion are illustrated by the resistivity calculations depicted in Figure 2. It is assumed that a depleted zone 50 μm thick exists under a continuously replaced outer layer, 2 mm thick with a resistivity which is controlled principally by the sodium addition rate. Initially, the inner and outer layers have the same resistivity, and point 1 on Figure 2 would correspond to day 5 on Figure 1. As sodium migration away from the collection plate occurs, the depleted zone would form, and the resultant resistivity would increase along line 1 until a limiting value is reached in the depleted zone. This point (point 2 in Figure 2) would approximately correspond to day 55 in Figure 1. As the outer layer of ash is replaced by conditioned ash of approximately 1×10^9 ohm-cm resistivity, the resultant resistivity would decrease along line 2 until an equilibrium is reached between the thermally-induced chemical diffusion process of sodium ions into the depleted zone and the ionization and electrical transport of sodium ions out of the depleted zone due to the electric field intensity. Point 3 on Figure 2 can correspond to an interim time period, such as day 65, in the recovery segment illustrated in Figure 1. At some time, illustrated by point 4 on Figures 1 and 2, an equilibrium between the thermal and electrical processes should be obtained past which no further reduction in resultant resistivity would be realized.

The depleted zone resistivity values depicted in Figure 2 have not been explicitly determined because of the difficulty of isolating a layer of 50 μm thickness and measuring its resistivity. However, the concept of sodium depletion due to current transport through fly ash has been demonstrated in the laboratory. Sodium concentrations were determined as

Table I. Lansing Smith unit 2—hot-side ESP[a]

Test	Efficiency, %	Penetration, %	Power, KW[b]	SCA, ft²/ KACFM	Na_2O, wt%	Date
Baseline 1	99.88	0.12	294	324	0.33	3/14–3/19
Baseline 2	98.21	1.79	47	313	0.32	4/22–5/2
Conditioning 1	99.64	0.36	157	322	0.96	5/14–5/24
Conditioning 2	99.71	0.29	258	329	1.90	6/17–6/20

[a] Data taken across hot-side ESP which is followed by a cold-side ESP.
[b] Calculated from T-R panel meters.

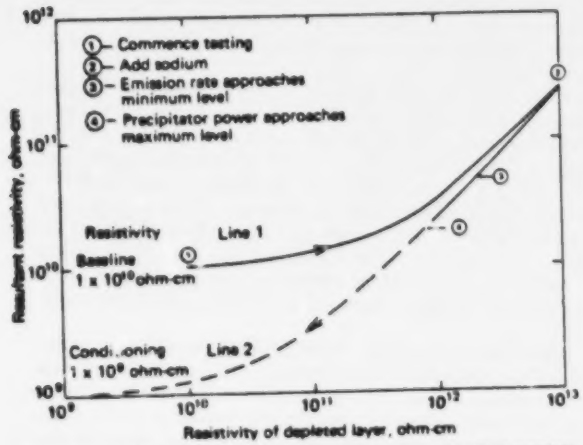

Figure 2. Depiction of hypothesized conditioning process. Resultant resistivity calculated assuming a series circuit comprised of a 50 μm depleted zone and a 2000 μm outer layer.

a function of distance from the anode of a fly ash specimen subjected to an applied voltage. The migration of sodium was established, and it was found that the major portion of charge transport could be accounted for by the sodium migration.[4] The high resistivity characteristic of a residual dust layer was demonstrated by determining the resistivity of a thin ash layer remaining on a section of collection electrode removed from the Lansing Smith ESP. The measurement was conducted in a laboratory apparatus at 350°C, and indicated a resistivity value in excess of 10^{12} ohm-cm.

The concept of chemical diffusion of sodium into a sodium-depleted zone of fly ash has also been indirectly demonstrated in the laboratory. The demonstration consisted of the observation of an increase in current with time at constant applied voltage in a wire-plate corona apparatus in which a conditioned ash layer was overlaid onto a depleted zone of high resistivity fly ash remaining on a simulated collection electrode. The experiment was conducted with Lansing Smith ash at 350°C.

It is anticipated that the equilibrium point obtained (point 4) in Figure 2 will be a function of ash chemistry, operating temperature, and certain design characteristics of the precipitator. It would therefore be inappropriate to assume that the results obtained at Lansing Smith could be quantitatively transferable to other installations which have similar symptoms but different operating parameters. Qualitatively, however, the results discussed herein are believed to be generally applicable.

Figure 3 illustrates voltage/current relationships from an outlet TR set for the Baseline 1, Baseline 2, and Conditioning 1 test series. The degradation of the electrical conditions between the Baseline 1 and Baseline 2 test series is readily apparent, as is the improvement effected by the conditioning process in the Conditioning 1 series. In general, the conditioning process produced a more pronounced improvement in the outlet electrical set operation than was the case for the inlet sets. This observation is consistent with the sodium depletion and chemical back-diffusion processes previously discussed. These processes would be expected to be more evident in the outlet fields due to the higher current densities and thinner dust layers which exist at this location.

Figure 4 displays fractional efficiencies derived from impactor traverses at the inlet and outlet sampling locations during the three indicated test series. These data show the same trends as the previously presented overall efficiencies, and provide additional insight into the ESP performance.

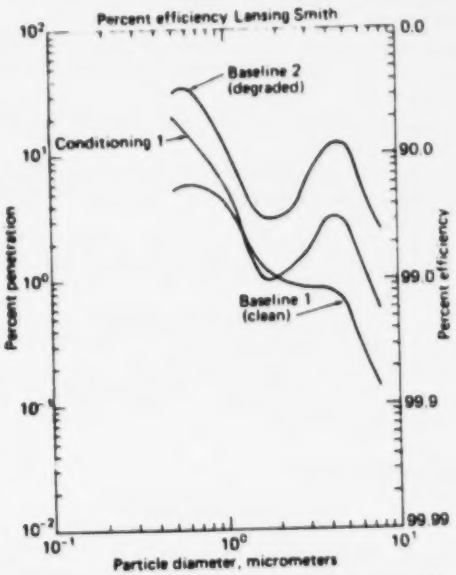

Figure 4. Fractional efficiency curves from hot-side ESP.

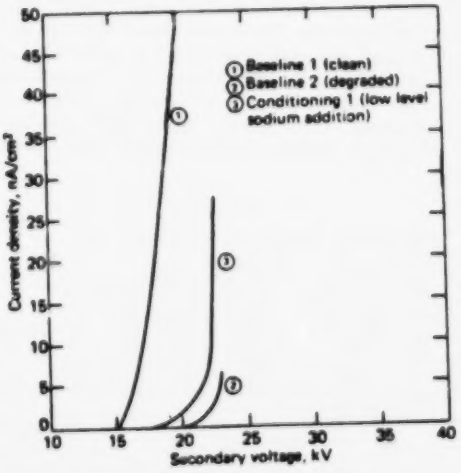
① Baseline 1 (clean)
② Baseline 2 (degraded)
③ Conditioning 1 (low level sodium addition)
Current density, nA/cm²
Secondary voltage, kV

Figure 3. Voltage-current curves for T-R set L.

Specifically, it is apparent that the degraded condition results in extremely poor submicron particle collection efficiencies. This phenomenon is consistent with the high plume opacities which are observed for an ESP operating in a degraded state. It is also of interest to note that the minimum in collection efficiency occurring in the 5 μm diameter region is greatly reduced for the Baseline 1 data set. This minimum is usually associated with rapping reentrainment, and would be expected to be reduced during a test series with the electrodes in a relatively clean condition.

Chemical Analyses

Coal analyses for the four test series of interest are given in Table II. These data illustrate that the coal supply provided a relatively uniform composition for the test program. Chemical composition data for ash samples obtained from isokinetic traverses of the inlet sampling locations are given

Table II. Lansing Smith coal analyses.

	Baseline 1						Baseline 2					
	3/14/80		3/17/80		3/19/80		4/24/80		4/28/80		4/30/80	
Date	As received	Dry	As received	Dry	As received	Dry	As received	Dry	As received	Dry	As received	Dry
% Moisture	6.45		5.70		5.93		7.66		7.80		5.34	
% Carbon	66.42	71.00	66.51	70.53	68.53	72.85	64.79	70.16	65.99	71.57	67.84	71.66
% Hydrogen	3.87	4.14	4.10	4.35	3.79	4.03	3.97	4.30	3.86	4.18	3.95	4.17
% Nitrogen	1.48	1.58	1.47	1.55	1.25	1.33	1.31	1.42	1.54	1.67	1.45	1.53
% Chlorine	0.02	0.02	0.03	0.04	0.04	0.05	0.04	0.05	0.02	0.02	0.03	0.04
% Sulfur	0.83	0.89	0.72	0.76	0.71	0.76	0.71	0.77	0.64	0.69	0.71	0.75
% Ash	13.10	14.00	12.97	13.75	12.98	13.80	12.82	13.88	12.26	13.30	12.94	13.67
% Oxygen	7.83	8.37	8.50	9.01	6.77	7.18	8.70	9.42	7.89	8.57	7.74	8.18
% Volatile	25.29	27.03	25.05	26.56	25.34	26.94	24.63	26.67	25.15	27.28	25.79	27.25
Btu/lb	11625	12426	11738	12447	11684	12421	11488	12441	11561	12539	11850	12518

	Conditioning 1						Conditioning 2			
Date	5/14/80		5/20/80		5/22/80		6/17/80		6/19/80	
% Moisture	5.72		5.65		7.42		5.53		6.16	
% Carbon	66.75	70.80	67.15	71.17	65.12	70.36	70.92	75.07	68.91	73.43
% Hydrogen	3.94	4.18	3.96	4.20	3.94	4.26	3.16	3.34	3.69	3.93
% Nitrogen	1.52	1.62	1.26	1.34	1.51	1.63	1.15	1.22	1.34	1.43
% Chlorine	0.04	0.04	0.04	0.04	0.02	0.03	0.03	0.03	0.02	0.02
% Sulfur	0.77	0.82	0.83	0.88	0.82	0.89	0.78	0.83	0.83	0.88
% Ash	13.00	13.79	13.27	14.06	12.72	13.74	12.98	13.74	12.86	13.70
% Oxygen	8.26	8.75	7.84	8.31	8.43	9.09	5.45	5.77	6.19	6.61
% Volatile	25.27	26.80	25.27	26.78	25.14	27.15	25.90	27.42	25.91	27.61
% Fixed Carbon	56.01	59.41	55.81	59.16	54.72	59.11	55.59	58.84	55.07	58.69
Btu/lb	11742	12454	11752	12456	11564	12491	11757	12445	11764	12536

in Table III. These data indicate that, except for the intentional changes in Na_2O concentration and variations in loss on ignition, the fly ash composition was also relatively constant. The undesirably high values of loss on ignition have historically been a problem at Plant Lansing Smith when the relatively low-volatile South African coal is the fuel source.

In addition to the standard methods of chemical analysis, samples obtained from impactors traversing the outlet of the precipitator were subjected to analysis with a scanning electron microscope used in the x-ray mode. These analyses indicated that the sodium concentration increased as particle size decreased, which is consistent with the assumed decomposition and subsequent condensation of sodium compounds on the fly ash surface. This observation was also made by chemically analyzing particle size fractions obtained from Bahco classification. The low values, Table III, for soluble sodium suggest that the conditioning agent is well distributed and has become an integral part of the fly ash surface rather than existing as discrete particles of sodium compounds.

Table IV provides flue gas composition data obtained during the test series. Of particular interest are the sulfur trioxide data, which were obtained with the controlled condensation method. These data indicate that the addition of sodium sulfate did not cause the sulfur trioxide concentration to increase at the ESP inlet. These results are consistent with the expected decomposition of sodium sulfate at furnace flame temperature.

Boiler Operating Considerations

The effect of the added sodium on the slagging and fouling tendency of the coal was of concern because of the general association of sodium with slagging and fouling problems. The coal and ash data were submitted to a consultant knowledgeable in this field for his evaluation of the effect of the added sodium sulfate on ash characteristics. The conclusions were as follows:[5]

- Addition of sodium sulfate to the coal was at levels too low to affect slagging significantly. In no case did the total alkalies in the ash samples exceed 2.8%, whereas about 6% is necessary to increase the slagging index appreciably.

Table III. Lansing Smith ash analyses from inlet mass train samples.

Sample	Baseline 1		Baseline 2		Conditioning 1			Conditioning 2			
Date	3/14/80	3/17/80	4/28/80	4/30/80	5/14/80	5/20/80	5/22/80	6/17/80	6/17/80	6/18/80	6/18/80
Li_2O	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Na_2O	0.33	0.33	0.31	0.33	0.86	1.1	0.91	1.9	1.9	1.8	2.0
K_2O	0.49	0.46	0.45	0.45	0.45	0.49	0.47	0.51	0.50	0.50	0.52
MgO	2.4	2.5	2.2	2.4	2.3	2.2	2.2	2.0	2.1	2.1	2.1
CaO	10.0	9.4	8.4	9.0	8.9	8.1	8.2	7.3	7.6	7.8	7.6
Fe_2O_3	5.8	4.9	5.4	5.8	5.8	4.9	4.9	5.4	4.9	5.4	5.4
Al_2O_3	34.0	34.7	35.5	34.9	34.4	35.2	35.2	34.7	35.7	34.4	35.1
SiO_2	40.8	40.9	41.9	39.8	39.6	40.8	41.4	39.8	40.5	39.8	40.0
TiO_2	2.0	1.6	1.8	1.7	1.8	1.8	1.8	1.9	1.9	2.0	1.9
P_2O_5	3.0	3.1	3.1	2.8	2.8	2.8	2.8	2.6	2.7	2.6	2.7
SO_3	0.5	0.7	0.6	0.7	0.9	0.9	0.8	1.1	0.9	1.3	0.8
LOI		12.6	12.6	15.2	16.5	13.0	15.9	6.5	14.8	7.3	15.0
Soluble Na, as Na_2O		0.06	0.06	0.10	0.07	0.08	0.08				
Soluble $SO_4^=$			0.28		0.34	0.39	0.59				

Table IV. Flue gas composition.

Date	H_2O %	O_2 %	CO_2 %	SO_2 ppm	SO_3 ppm
Baseline 1					
3/14/80	6.3	5.2	14.8	578	2.3
3/15/80	7.2	4.7	15.4	438	1.9
3/17/80	7.8	5.3	14.4	510	2.7
3/18/80	7.2	4.4	14.6	465	3.0
3/19/80		7.4	12.7	398	2.2
Baseline 2					
4/23/80	8.9	5.2	15.2	560	2.4
4/24/80	7.7	4.4	15.1	528	3.3
4/25/80	8.4	5.2	14.0	525	2.1
4/26/80	8.7	4.2	14.5	500	1.8
4/28/80	7.8	4.5	14.1	493	3.8
4/29/80	7.2	4.8	14.4	485	2.7
4/30/80	7.8	4.5	13.6	453	2.2
5/01/80	7.9	4.2	14.8	485	2.9
5/02/80	7.6	5.3	14.7	500	2.7
Conditioning 1					
5/14/80	8.9	4.2	15.2	545	1.4
5/15/80	8.1	3.8	15.8	525	1.5
5/20/80	8.2	4.4	15.3	490	1.8
5/21/80	7.9	4.5	15.3	565	1.4
5/22/80	9.1	4.4	15.1	533	1.6
5/23/80	8.8	3.9	14.7	530	2.0
5/24/80	8.8	4.4	14.6	530	1.6

- Addition of sodium sulfate to the coal also was not sufficient to increase the fouling tendency in these tests. The highest alkali content on the basis of the coal was only 0.32%, with 0.30% commonly accepted as the nominal limit below which fouling from alkalies is not likely.

These conclusions are consistent with observations of the boiler which were performed after the Conditioning 2 test series was completed. These observations indicated no slagging or fouling problems at any location.

Another area of concern is the effect of the added sodium on high temperature corrosion due to the presence of a liquid phase consisting of complex alkali sulfates. However, a definitive answer to the question of whether the added sodium produced an appreciable change in already existing corrosion rates is not expected to be obtained with the current test series.

Laboratory Experiments

Figure 5 gives results from laboratory measurements of resistivity on proportionate blends of hopper samples obtained during the indicated test series. These results clearly show the effect of the added conditioning agent. In general, the resistivity data are consistent with previously developed prediction techniques.[6] The undesirably high concentration of carbon in the ash produced experimental difficulties, but the results shown are not believed to be affected by this problem.

Work conducted during the course of this project has illustrated the sodium depletion process using Lansing Smith ash in both parallel plate and corona wire-and-plate experimental arrangements. These experiments will be reported in the project final report, which is expected to be available later this year.

Other work in progress includes an analysis of the precipitator performance using a mathematical model and particle charge vs. size data which are obtained at the ESP outlet. This work is expected to provide a basis for estimating collection efficiency performance improvements which may be obtained for a given change in the useful current and voltage delivered by the precipitator TR sets as a result of sodium conditioning.

Conclusion

Sodium conditioning produced by sodium sulfate addition to the coal supply has been shown to provide an effective

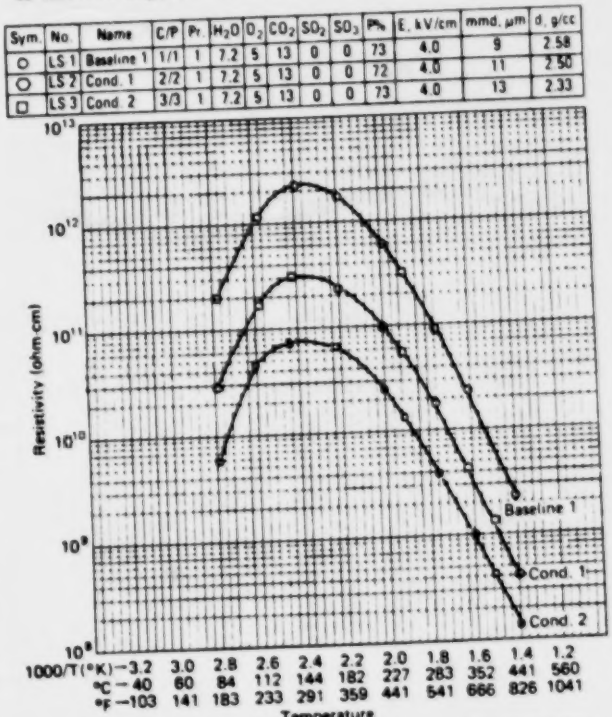

Figure 5. Resistivity/temperature relationship for proportionately blended hopper samples

means of improving the performance of a hot-side ESP which has undergone the sodium-depletion, high resistivity pattern of performance deterioration. The performance improvement can be explained as an equilibrium process in the depleted zone in which sodium is transported to the depleted region by a thermally induced chemical diffusion process. The reduction of ash resistivity appears to depend upon the equilibrium which is attained between the competing chemical and electrical transport processes. The equilibrium point, in turn, is expected to depend upon ash composition and certain design and operating parameters of the precipitator.

Although the results described in this report are believed to be of general significance, certain characteristics of the operating parameters at Lansing Smith are noteworthy with regard to the success of the conditioning process. First, ash concentration, ash compos'tion, and boiler design allowed the addition of the required amount of sodium without the creation of operating problems in the boiler. Secondly, the calcium content of the coal was moderate, and there is some evidence to indicate that high calcium concentrations would require more sodium addition for the same degree of resistivity reduction. The applicability of the process for other ash chemistries and operating circumstances, therefore, remains to be determined.

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